CG Assignment no. 1 & 2 (combined)

Computer Graphics Assignment

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Branch: CSE1   Course code: CS6401

Course Title :- computer graphics,

1) write procedure for the scan conversion of conic sections if it is represented in parabolic path and hyperbolic curve.

Ans:- parabolas and hyperbolas possess axis of symmetry. Also in general, the equation of a conic section can be written as:

$$Ax^2 + By^2 + Cxy + Dx + Ey + F = 0 \quad \text{---} (1)$$

where A, B, C, D, E and F are constants which determine which curve is represented.

$$B^2 - 4AC \begin{cases} < 0, & \text{ellipse or circle} \\ = 0, & \text{parabola} \\ > 0, & \text{hyperbola.} \end{cases}$$

For scan conversion of these curves, we can use a slightly modified ellipse algorithm, or to be precise a modified midpoint ellipse algorithm. To do this, we need to select an appropriate form of eqn — (1) for either parabola or hyperbola.

Next, we use the selected functions to set up decision parameter 'p' for the regions where:-

(i) the slope of curve is less than 1

(ii) the slope of curve is greater than 1

the modified midpoint ellips algorithms then can be used to obtain points on one side of the aforesaid regions (half of symmentry) in left, we can use symmetry to determine the remaining points.

Q2 Explain detailed algorithm for the Nicholl-Lee-Nicholl approach to line clipping for any input pair of line endpoint:-

Ans:-

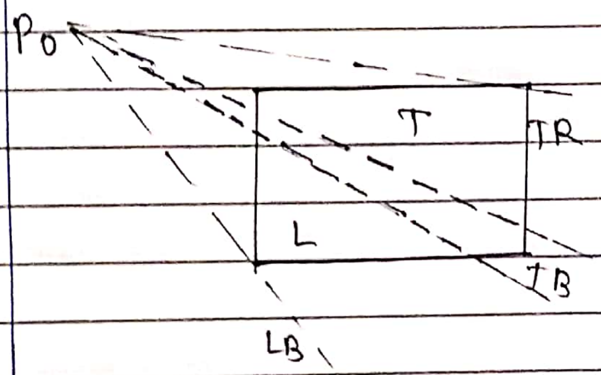
1	2	3
4	5	6
7	8	9

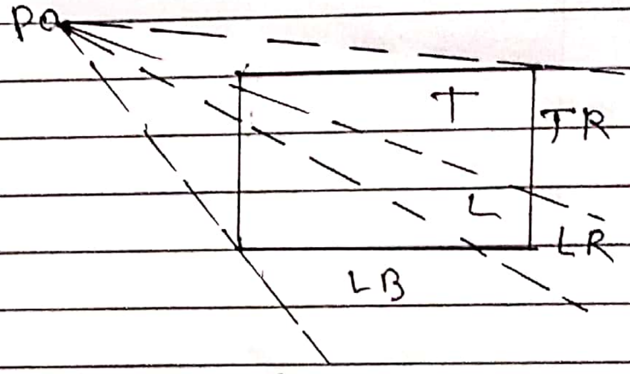
Let us assume that region 5 is the clipping window. So, the line /points present in region 5 will be display only.

Let P_0 and P_1 be two endpoint of a line. First we determine the position of point P_0 in the 9 regions. Here we only need to consider regions 1, 4 and 5 because rest of the regions are symmetrical -ry to these regions.

let us assume that both P_0 and P_1 are not in the window. so we determine position of P_1 relative to P_0. for this, new boundaries are created corresponding to position of P_0 in region 1, 4 or 5.

(i) If P_0 is in region 1.

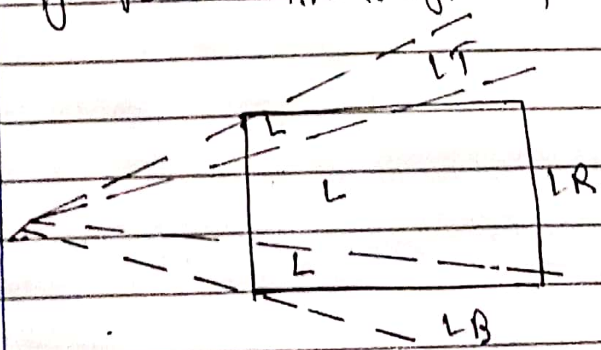




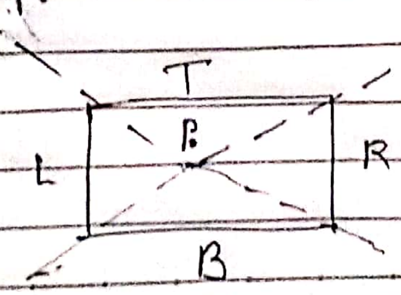
(a) used when P_0 is closer to left clipping boundry

(b) used when P_0 is closer to upper clipping boundry.

(ii) If P_0 is in region 4



iii) If P_0 is in region 5



For determining position of P_1, we compare the slopes of the boundaries for these new boundary to slope of the line.

• condition for clipping

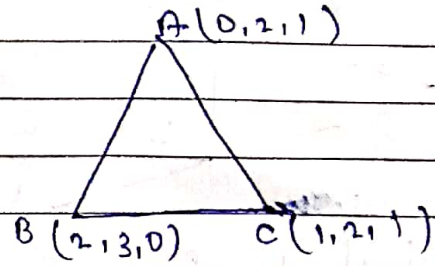
(i) (a) P_0 is region 1
If P_1 is in T, L, TR, TB, LR or LB, a unique clipping window ~~border~~ border is determined and intersection is calculate, otherwise the line is rejected.

(ii) P_0 is in region 4
If P_1 is in L, left boundary is used to calculate intersection point and cliping similar for LT, LR, and LB. If P_1 is not in any region, the line is rejected.

Q 3) A triangle is defined by 3 vertices A (0,2,1), B (2,3,0), C (1,2,1) find the final coordinates after it is rotated by 45 degree around a line joining the points (1,1,1) and (0,0,0).

Ans:- (0,0,0) P_0 ——— (1,1,1) P_2

$|P_1P_2| = \sqrt{1^2+1^2+1^2} = \sqrt{3}$



Direction cosines of P_1P_2 are

$a = \frac{1-0}{\sqrt{3}} = \frac{1}{\sqrt{3}}$, $b = \frac{1-0}{\sqrt{3}} = \frac{1}{\sqrt{3}}$, $c = \frac{1-0}{\sqrt{3}} = \frac{1}{\sqrt{3}}$

Since the axis of rotation (P_1P_2) passes through the origin, we do not need to translate it to origin and hence we do not require a translation matrix.

Now, we rotate the P_1P_2 about passes through the origin, ~~we do~~ x-axis by an angle α where.

$\cos\alpha = \frac{c}{d}$ and $\sin\alpha = \frac{b}{d}$ $\cos\alpha = \frac{1}{\sqrt{2}}$, $\sin\alpha = \frac{1}{\sqrt{2}}$

where $d = \sqrt{b^2 + c^2}$ $\Rightarrow d = \sqrt{\frac{1}{3} + \frac{1}{3}} = \sqrt{\frac{2}{3}}$

Rotation matrix

$$\therefore R_x(\alpha) = \begin{vmatrix} 0 & 0 & 0 & 0 \\ 0 & \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$\text{And } R_x^{-1}(\alpha) = \begin{vmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

(Inverse rotation matrix)

Now we rotate about Y-axis by an angle β where

$\cos\beta = d.$ $\Rightarrow \cos\beta = \sqrt{\frac{2}{3}}$

and $\sin\beta = -a$ $\Rightarrow \sin\beta = \frac{-1}{\sqrt{3}}$

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Rotation matrix

$$R_y(p) = \begin{bmatrix} \sqrt{\frac{2}{3}} & 0 & \frac{-1}{\sqrt{3}} & 0 \\ 0 & 1 & 0 & 0 \\ \frac{1}{\sqrt{3}} & 0 & \sqrt{\frac{2}{3}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

And $R_y^{-1}(p) = \begin{bmatrix} \sqrt{\frac{2}{3}} & 0 & \frac{-1}{\sqrt{3}} & 0 \\ 0 & 1 & 0 & 0 \\ \frac{-1}{\sqrt{3}} & 0 & \sqrt{\frac{2}{3}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

Now the axis is aligned to z-axis. for rotation of triangle about z-axis by 45°.

Rotation matrix, $R_z(45°) = \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

The transformation matrix for rotation of the triangle can be expressed as:

$$R(45°) = R^{-1}_x(\alpha) \cdot R^{-1}_y(\beta) \cdot R_z(45°) \cdot R_y(\beta) \cdot R_x(\alpha)$$

$$R_y(p) \cdot R_x(\alpha) = \begin{bmatrix} \sqrt{\frac{2}{3}} & 0 & \frac{-1}{\sqrt{3}} & 0 \\ 0 & 1 & 0 & 0 \\ \frac{1}{\sqrt{3}} & 0 & \sqrt{\frac{2}{3}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \\ 0 & 1/\sqrt{2} & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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$$= \begin{bmatrix} \sqrt{\frac{2}{3}} & -1/\sqrt{6} & -1/\sqrt{6} & 0 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ 1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_x^{-1}(\alpha) \cdot R_y^{-1}(\beta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \sqrt{\frac{2}{3}} & 0 & \frac{1}{\sqrt{3}} & 0 \\ 0 & 1 & 0 & 0 \\ \frac{-1}{\sqrt{3}} & 0 & \sqrt{\frac{2}{3}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \sqrt{\frac{2}{3}} & 0 & 1/\sqrt{3} & 0 \\ -1/\sqrt{6} & 1/\sqrt{2} & 1/\sqrt{3} & 0 \\ -1/\sqrt{6} & -1/\sqrt{2} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Now, $R_x^{-1}(\alpha)\, R_y^{-1}(\beta)\, R_z(45^\circ)\, R_y(\beta)\, R_x(\alpha)$ is

$$\begin{bmatrix} \sqrt{2/3} & 0 & 1/\sqrt{3} & 0 \\ -1/\sqrt{6} & 1/\sqrt{2} & 1/\sqrt{3} & 0 \\ -1/\sqrt{6} & -1/\sqrt{2} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \sqrt{\frac{2}{3}} & -1/\sqrt{6} & -1/\sqrt{6} & 0 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ \frac{1}{\sqrt{3}} & 1/\sqrt{3} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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$$= \begin{bmatrix} \frac{2}{\sqrt{6}} & 0 & 1/\sqrt{3} & 0 \\ -1/\sqrt{6} & 1/\sqrt{2} & 1/\sqrt{3} & 0 \\ -1/\sqrt{6} & -1/\sqrt{2} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1/\sqrt{3} & -1/\sqrt{12}-\frac{1}{2} & \frac{-1}{\sqrt{12}}+\frac{1}{2} & 0 \\ 1/\sqrt{3} & -1/\sqrt{12}+1/2 & -1/\sqrt{12}-\frac{1}{2} & 0 \\ 1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{6}}{6}-\frac{\sqrt{2}}{6}+\frac{1}{3} & -\frac{\sqrt{2}}{6}+\frac{1}{3}+\frac{\sqrt{6}}{6} & 0 \\ -\frac{\sqrt{2}}{6}+\frac{1}{3}+\frac{\sqrt{6}}{6} & \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{6}}{6}-\frac{\sqrt{2}}{6}+\frac{1}{3} & 0 \\ -\frac{\sqrt{6}}{6}-\frac{\sqrt{2}}{6}+\frac{1}{3} & -\frac{\sqrt{2}}{6}+\frac{1}{3}+\frac{\sqrt{6}}{6} & \frac{1}{3}+\frac{\sqrt{2}}{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$= K(45^\circ)$

$$\text{vertices of triangle } V = \begin{array}{c} \begin{matrix} A & B & C \end{matrix} \\ \begin{bmatrix} 0 & 2 & 1 \\ 2 & 3 & 2 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix} \end{array}$$

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Multiplying $R(45^0)$ and V_1, we get the final coordinate of triangle as.

$$\begin{bmatrix} -\sqrt{6}/6 - 3\sqrt{2}/6 + 1 & \sqrt{2}/6 - 3\sqrt{6}/6 + 5/3 & 4/3 - \left(\frac{\sqrt{6}+\sqrt{2}}{6}\right) \\ 2\sqrt{2}/3 - \sqrt{6}/6 - \frac{\sqrt{2}}{6} + 1 & 4\sqrt{2}/6 + 2\sqrt{6}/6 + 5/3 & 4/3 - 2\sqrt{2}/6 \\ -\sqrt{2}/3 + \sqrt{6}/6 + 1 & -5\sqrt{2}/6 + \sqrt{6}/6 + 5/3 & 4/3 + \frac{\sqrt{6} - \sqrt{2}}{6} \\ 1 & 1 & 1 \end{bmatrix}$$

Original coordinates	final coordinates
A(0, 2, 1)	A (-0.115, 1.298, 0.936)
B (2, 3, 0)	B (0.677, 3.425, 0.896)
C (1, 2, 1)	C (0.689, 0.861, 1.505)

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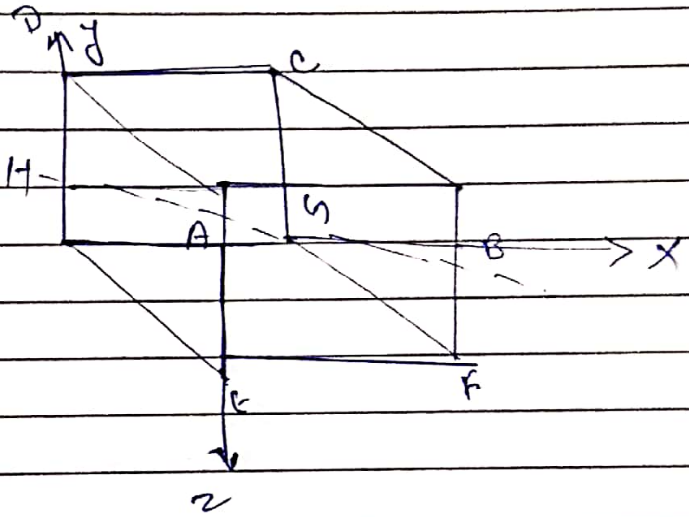
Q(4) A cub cie defined by 8 vertice A (0,0,0), B (2,0,0), C (2,2,0), D (0,2,0), E (0,0,2), F (2,0,2), G (2,2,2) and H (0,2,2). find the final coordinates after it cie rotated by 45 degree around a line joining the point (2,0,0), and (0,2,2) :-

Ans:-



Axis of rotation cie BH.
first, we need to translate BH to origin.
Translation matrix.

$$T = \begin{bmatrix} 1 & 0 & 0 & -2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad T^{-1} = \begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

T^{-1} = Inverse transformation matrix of translation T.

H(0,2,2) B(2,0,0)

$$|BH| = \sqrt{2^2 + 2^2 + 2^2} = 2\sqrt{3}$$

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Direction cosines of BH:

$a = \frac{0-2}{2\sqrt{3}} = \frac{-1}{\sqrt{3}}$, $b = \frac{2-0}{2\sqrt{3}} = \frac{1}{\sqrt{3}}$, $c = \frac{2-0}{2\sqrt{3}} = \frac{1}{\sqrt{3}}$

Now we need to rotate BH about x-axis by an angle α where.

$\cos\alpha = \frac{c}{d}$ and $\sin\alpha = \frac{b}{d} \Rightarrow \cos\alpha = \frac{1}{\sqrt{2}}$, $\sin\alpha = \frac{1}{\sqrt{2}}$

and $d = \sqrt{b^2+c^2} \Rightarrow d = \sqrt{\frac{1}{3}+\frac{1}{3}} = \sqrt{\frac{2}{3}}$

Rotation matrix

$$R_x(\alpha) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$R_x^{-1}(\alpha) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$R_x^{-1}(\alpha)$ is inverse translation matrix of $R_x(\alpha)$

we shall now rotate the rotated BH about y axis by an angle β so that it gets aligned along z-axis

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$\cos\beta = d \Rightarrow \cos\beta = \sqrt{\frac{2}{3}}$

$\sin\beta = -a \Rightarrow \sin\beta = \frac{1}{\sqrt{3}}$

Rotation matrix

$$R_y(\beta) = \begin{bmatrix} \sqrt{2/3} & 0 & 1/\sqrt{3} & 0 \\ 0 & 1 & 0 & 0 \\ -1/\sqrt{3} & 0 & \sqrt{2/3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad R_y^{-1}(\beta) =$$

$$\begin{bmatrix} \sqrt{2/3} & 0 & -1/\sqrt{3} & 0 \\ 0 & 1 & 0 & 0 \\ 1/\sqrt{3} & 0 & \sqrt{2/3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$R^{-1}_y(\beta)$ is the inverse rotation Matrix.

for rotation of the image, we rotate the image along Z-axis by 45° (as BH is aligned along Z-axis)

Rotation matrix

$$R_z(45^\circ) = \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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All the transformation for rotation of the cube can be written as.

$$R = T^{-1} R_x^{-1}(\alpha) . R_y^{-1}(\beta) . R_z(45^\circ) . R_y(\beta) . R_x(\alpha) . T$$

$$T^{-1} . R_x^{-1}(\alpha) . R_y^{-1}(\beta) .$$

$$\begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \sqrt{2/3} & 0 & -1/\sqrt{3} & 0 \\ 0 & 1 & 0 & 0 \\ 1/\sqrt{3} & 0 & \sqrt{2/3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \sqrt{2/3} & 0 & -1/\sqrt{3} & 0 \\ 0 & 1 & 0 & 0 \\ 1/\sqrt{3} & 0 & \sqrt{2/3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \sqrt{2/3} & 0 & -1/\sqrt{3} & 2 \\ 1/\sqrt{6} & 1/\sqrt{2} & 1/\sqrt{3} & 0 \\ 1/\sqrt{6} & -1/\sqrt{2} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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$R_y(\beta) \cdot R_x(\alpha) \cdot T$

$$= \begin{bmatrix} \sqrt{2/3} & 0 & 1/\sqrt{3} & 0 \\ 0 & 1 & 0 & 0 \\ -1/\sqrt{3} & 0 & \sqrt{2/3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & -2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \sqrt{2/3} & 0 & 1/\sqrt{3} & 0 \\ 0 & 1 & 0 & 0 \\ 1/\sqrt{3} & 0 & \sqrt{2/3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -2 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \sqrt{2/3} & 1/\sqrt{6} & 1/\sqrt{6} & -2\sqrt{2/3} \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ -1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} & 2/\sqrt{3} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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$$T^{-1}\, R_x^{-1}(\alpha) \cdot R_y^{-1}(\beta) \cdot R_z(45^\circ) \cdot R_y(\beta) \cdot R_x(\alpha) \cdot T$$

$$= \begin{bmatrix} \sqrt{2/3} & 0 & -1/\sqrt{3} & 2 \\ 1/\sqrt{6} & 1/\sqrt{2} & 1/\sqrt{3} & 0 \\ 1/\sqrt{6} & -1/\sqrt{2} & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \sqrt{2/3} & 1/\sqrt{6} & 1/\sqrt{6} & -2\sqrt{2/3} \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ -1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} & 2/\sqrt{3} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1/\sqrt{3} & -1/\sqrt{3} & -1/\sqrt{3} & 2 \\ 1/\sqrt{12}+1/2 & -1/\sqrt{12}+1/2 & 1/\sqrt{3} & 0 \\ 1/\sqrt{12}-1/2 & -1/\sqrt{12}-1/2 & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \sqrt{2/3} & 1/\sqrt{6} & 1/\sqrt{6} & -2\sqrt{2/3} \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ -1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} & 2/\sqrt{3} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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$$\begin{bmatrix} \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{6}}{6}-\frac{1}{3}+\frac{\sqrt{2}}{6} & -\frac{1}{3}+\frac{\sqrt{2}}{6}+\frac{\sqrt{6}}{6} & \frac{4}{3}-\frac{2\sqrt{3}}{3} \\ -\frac{1}{3}+\frac{\sqrt{2}}{6}+\frac{\sqrt{6}}{6} & \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{6}+\frac{1}{3}+\frac{\sqrt{6}}{6} & -\frac{\sqrt{6}}{3}-\frac{\sqrt{2}}{3}+\frac{2}{3} \\ -\frac{\sqrt{6}}{6}-\frac{1}{3}+\frac{\sqrt{2}}{6} & -\frac{\sqrt{6}}{6}-\frac{\sqrt{2}}{6}+\frac{1}{3} & \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$= R(45^\circ)$

the vertices of the cube can be written in a matrix as.

$$V = \begin{array}{c} \begin{array}{cccccccc} A & B & F & E & H & D & C & G \end{array} \\ \begin{bmatrix} 0 & 2 & 2 & 0 & 0 & 0 & 2 & 2 \\ 0 & 0 & 0 & 0 & 2 & 2 & 2 & 2 \\ 0 & 0 & 2 & 2 & 2 & 0 & 0 & 2 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \end{array}$$

To get the final coordinates, we multiply R and V. we get,

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$$
\begin{array}{cccc}
A & B & F & E \\
\left[\begin{array}{cccc}
\frac{4}{3}+\frac{2\sqrt{2}}{3} & 2 & \frac{\sqrt{2}}{3}+\frac{\sqrt{6}}{3}+\frac{4}{3} & -\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} \\
-\frac{\sqrt{6}}{6}-\frac{\sqrt{2}}{3}+\frac{2}{3} & 0 & -\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} & \frac{4}{3}-\frac{2\sqrt{3}}{3}+\frac{4}{3} \\
-\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} & 0 & \frac{2}{3}+\frac{2\sqrt{2}}{3} & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} \\
1 & 1 & 1 & 1
\end{array}\right.
\end{array}
$$

$$
\begin{array}{cccc}
H & D & C & G \\
\left.\begin{array}{cccc}
0 & -\frac{\sqrt{6}}{3}-\frac{\sqrt{2}}{3}+\frac{2}{3} & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} & \frac{2}{3}+\frac{2\sqrt{2}}{3} \\
2 & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} & \frac{2}{3}+\frac{2\sqrt{2}}{3} & \frac{\sqrt{2}}{3}+\frac{\sqrt{6}}{3}+\frac{4}{3} \\
2 & \frac{4}{3}-\frac{2\sqrt{2}}{3} & -\frac{\sqrt{6}}{3}-\frac{\sqrt{2}}{3}+\frac{2}{3} & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} \\
1 & 1 & 1 & 1
\end{array}\right]
\end{array}
$$

In decimal the new/final co-ordinates are listed as follows.

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Original co-ordinates	Final coordinates
A (0, 0, 0)	A (0.39, −0.621, 1.011)
B (2, 0, 0)	B (2, 0, 0)
C (2, 2, 0)	C (0.988, 1.609, −0.621)
D (0, 2, 0)	D (−0.621, 0.988, 0.39)
E (0, 0, 2)	E (1.011, 0.39, 2.621)
F (2, 0, 2)	F (2.621, 1.011, 1.609)
G (2, 2, 2)	G (1.609, 2.621, 0.988)
H (0, 2, 2)	H (0, 2, 2)

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Q5 Explain different types of parallel projections with its normalized transformation matrix representation. Also explain the perspective projection equation in special cases if the projection reference point could be limited to positions along the zview axis.

Ans:- There are two types of parallel projections:-

(i) Orthographic projection:-

→ transformation of object description to a view plane along lines that are all parallel to the normal vector N of the view plane is called as orthographic projection.

the normalized transformation matrix for the projection is

$$M_{ortho,norm} = \begin{bmatrix} \frac{2}{x^w_{max} - x^w_{min}} & 0 & 0 & \frac{-x^w_{max} + x^w_{min}}{} \\ 0 & \frac{2}{y^w_{max} - y^w_{min}} & 0 & \frac{-y^w_{max} + y^w_{min}}{y^w_{max} - y^w_{min}} \\ 0 & 0 & \frac{-2}{z_{near} - z_{far}} & \frac{z_{near} + z_{far}}{z_{near} - z_{far}} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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Here, position ($x_{min}, y_{min}, z_{near}$) is mapped to the normalized position (-1, -1, -1) and position ($x_{max}, y_{max}, z_{far}$) is mapped to (1, 1, 1).

→ In orthographic projection a parallel projection transformation is produced in which the projection lines are perpendicular to the view plane.

→ Generally used to produce front, top and side view of an object.

(ii) Oblique projection :-

→ It is obtained by projecting ~~points~~ ~~along~~ points along parallel lines that are not perpendicular to the projection plane.

→ In this projection the view plane normal and the direction of projection is not same.

→ This projection is used to produce configuration such as front, side view and top view of an object.

The transformation matrix for oblique projection is :

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$$M_{oblique} = \begin{bmatrix} 1 & 0 & -\frac{V_{px}}{V_{pz}} & z_{vp} \cdot \frac{V_{px}}{V_{pz}} \\ 0 & 1 & -\frac{V_{py}}{V_{pz}} & z_{vp} \frac{V_{py}}{V_{pz}} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

the normalized transformation matrix for this is given by

$$\boxed{M_{oblique,norm} = M_{ortho,norm} \cdot M_{oblique}}$$

Special cases of perspective projection i.e if the projection reference point could be limited to positions along the the zview axis are explained below :-

Case I : when $x_{prp} = y_{prp} = 0$

we know the general equation of the perspective transformations as

$$x_p = x\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right) + z_{prp}\left(\frac{z_{vp} - z}{z_{prp} - z}\right)$$

and $$y_p = y\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right) + y_{prp}\left(\frac{z_{vp} - z}{z_{prp} - z}\right)$$

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putting $x_{prp} = 0$ and $y_{prp} = 0$, we get

$$x_p = x\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right) \quad y_p = y\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right)$$

Case II : when projection reference point is fixed at the co-ordinate origin i.e

$$(x_{prp}, y_{prp}, z_{prp}) = (0, 0, 0)$$

putting these values of x_{prp}, y_{prp} and z_{prp} in the general equation we get

$$x = x\left(\frac{z_{vp}}{z}\right) \quad y = y\left(\frac{z_{vp}}{z}\right)$$

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Q(6) What do you mean by Bezier Spline Curves? Explain with equations. design techniques using Bezier Curves.

Ans:- Bezier spline curve is a parameter curve in which control points are used. this method makes use of Bezier function which are a set of polynomials

Let we consider n+1 control points, denoted by $P_k = (x_k, y_k, z_k)$ where $0 \le k \le n$. using these points position vector $p(u)$ is formed which describes the path of Bezier polynomial function between p_0 and p_n

$$\boxed{p(u) = \sum_{k=0}^{n} p_k \, BEZ_{k,n}(u)} \quad , u \in [0,1]$$

where $BEZ_{k,n}(u)$ is the Bezier blending function also known as Bernstein polynomials and is given as :

$$\boxed{BEZ_{k,n}(u) = \binom{n}{k} u^k (1-u)^{n-k}}$$

some properties of Bezier curve are as follows.

i) The curve connects the first and last control points of the control polygon.

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(ii) The slope of tangent at the beginning of the curve is along the line joining first two control points, and the slope at the end of the curve is along the line joining the last two end points.

(iii) All control points impact the entire curve.

(iv) All the points on the curve lie inside the convex Hull of the control polygon.

(v) The order of the curve is related to the number of control points.

(vi) No lines can intersect the curve at more than two points if the control points form an open polygon hence, the curve is smooth and free of loops this is called variation. Diminishing property.

(vii) The curve is transformed by applying an affine transformation to its control points and generating the transformed curve from the transformed control points.

Design techniques:

→ Complicated curves or higher degree curves can be formed by joining several Bezier section of lower degree. This technique.

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→ gives a better local control over the curve

→ If the first section/piece of the curve has n control points and the next curve section has n control points, then we match curve tangents by placing control point p_1 at the position.

$$\boxed{p'_1 = p_n + \frac{n}{n_1}\left(p_n - p_{n-1}\right)}$$

~~(using the tangent property of Bezier curves)~~

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Q7 Define visible surface detection. Also explain different classification methods use for visible ~~surface~~ surface detection algorithms.

Ans:- In generalisation of realistic graphics displays determining what is visible within a scene from a chosen view position so that only the visible lines or surfaces should be displayed is known as visible surface detection or hidden surface elimination.

Different classification methods are used for visible surface detection algorithms. They are broadly classified in object-space methods and image-space method.

(i) Object space methods:-

→ Compares objects and parts of objects to each other within the scenes definition to determine which surface as a whole should be labelled visible.

(ii) Image space methods:-

→ In this method visibility is decided point by point at each pixel position on the projection plane. Some other methods that fall under these categories are listed below:-

(i) Back Face Detection:-

→ It is a fast and simple object - space methods.

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→ used to locate the back face of a polyhedron

→ Based on front back tests i.e a point (x, y, z) is behind a polygon surface if

$$Ax + By + Cz + D < 0$$

where A, B and C are plane parameters of polygon.

→ we can use the viewing position to test for back face

(ii) Depth buffer methode!-

→ It is an image space methode.

→ It compares the surface depth value throughout a scene for each pixel position on projection plane

→ Generally applied to scenes containing only polygon surface as the methode is easy to implement and the computation of depth values can be done quickly.

Drawback:

→ Deals only with opaque surface.

→ Cannot accumulate color values for more than one surface.

→ Performs needless calculation.

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(iii) A-buffer methode :-

→ It is an image space methode and is an extension of depth buffer method.

→ It is an anti aliasing, area averaging method

→ The buffer region, known as Accumulation buffer is used to store a variety of surface data and depth values.

(iv) Scan-line methode :-

→ it is an image space methode.

→ It computes and compares depth values along various scan lines for a scene.

→ During processing of a scan line all polygon surface projection of intersecting that line are examined for visibility.

→ After determining the visible surface of a pixel the surface color of that position is entered into frame buffer.

→ processing of surface is done using information from polygon tables.

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Table	information
→ Edge table	coordinate endpoints for each line inverse slope of each line pointer to surface-facet table.
→ surface-facet table	plane coefficient surface material properties pointer to edge table.

→ A flag for each surface is defined with "on" or "off" value to indicate whether a position along scan line is inside or outside the surface.

(v) Depth - sorting methods :-

→ Both image space and object space methods.
→ It is also called the painters algorithm
→ Surface are sorted in order of increasing depth and are scan-converted in order.

→ sorting with operation are carried out in both image and object space. and the scan conversion of polygon surface is done in image space.

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(vi) BSP – Tree methode :-

→ Both image space and object space methode.
→ Useful when the view reference point changes but the object in a scene are at fixed position.

→ it involves identifying surfaces that are behind or in front of the partitioning plane at ~~st~~ each step of the space relative to the viewing direction, until each node in the tree contains only one polygon.

(vii) Area subdivision method :-

→ It is an image space methode but object space method can be used to accomplish depth ordering of surface.

→ It takes advantage of ~~st~~ area coherance in a scene by locating part of single surface.

→ Four possible relationship between surfaces and area of subdivided new plane are as follows.

Surrounding surface :- Surface that completely ~~encl~~ enclose the area.

Inside surface :- surface that is completely inside ~~insid~~ the area.

Outside surface :- Surface that completely outside area.

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(viii) Octree methods:-

→ It involves dividing the solid object in an octree representation which is represented as a tree structure.

→ it is an extension of quadtree encoding Imaging in 2D.

→ it is generally used medical Imaging and other application that require display of object cross-section.

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Q(8) Are we using GPU model in our Normal pcs? what are the benefits for using an external GPU models / cards of heterogeneous system? Also explain the GPU pipeline using CUDA architecture by suitable diagrams.

Ans:- Every PC needs some sort of GPU (Graphics processing unit). This is due to the fact that absence of a GPU will lead to no image output at the display (monitor). These days the motherboards of the pcs come with an integrated GPU over it or on the ~~cpu~~ cpu itself. These GPUs are called integrated GPUs.

Benefits of integrated GPU.

→ user does not need to worry about GPU installation
→ power efficient
→ issues regarding drivers or compatibility is rare

Downside:

→ Performance is not good in demanding applications like games.

Integrated GPUs are very common in modern pcs they are capable of handling most of the graphics application.

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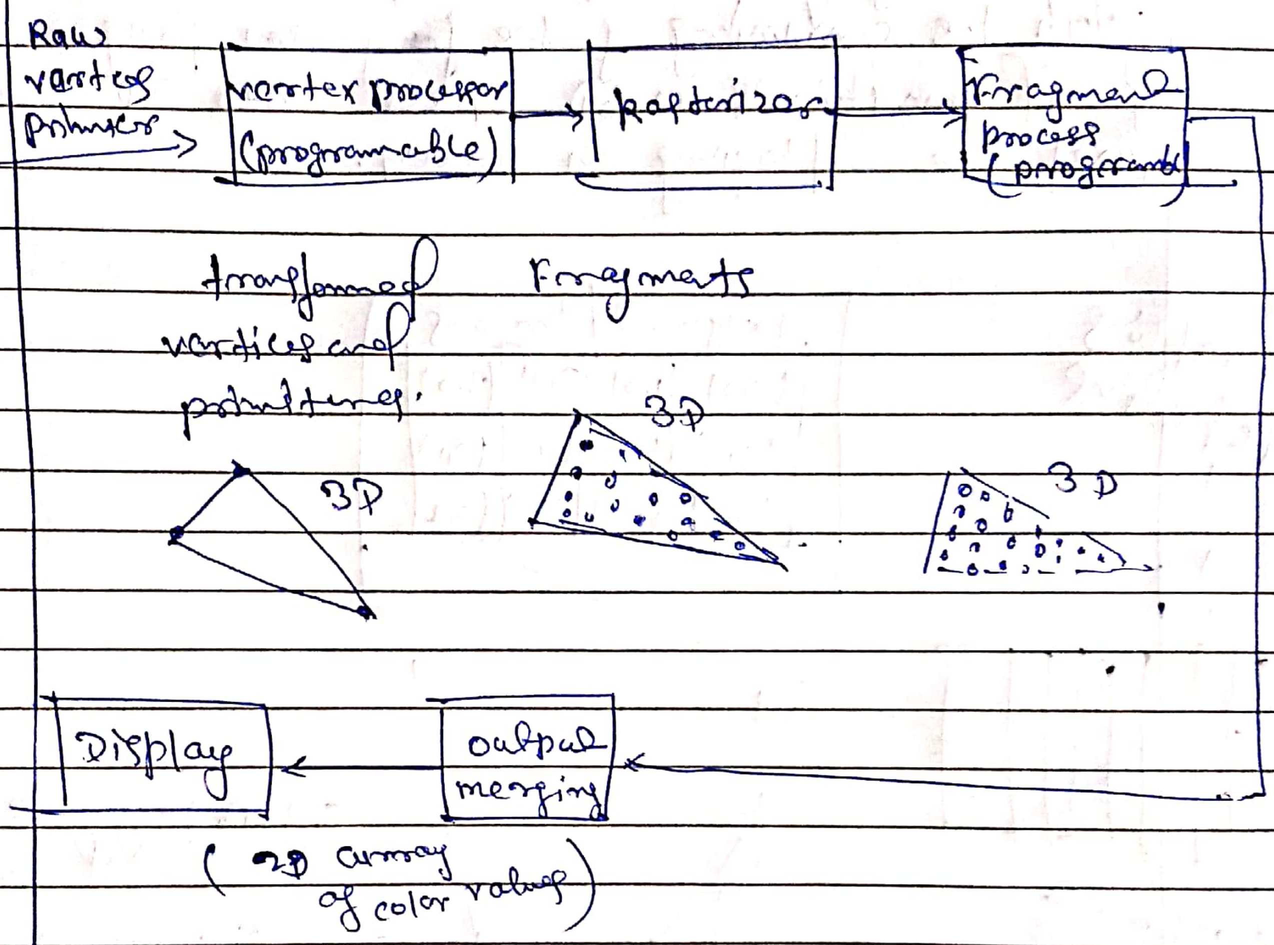
The graphical pipeline:-



- vertex processing :- In this phase the processing and transformation of individual vertices and normals is done.

- Rasterization → it is the process of converting each primitive (connected vertex) into a set of fragments. A fragment can be interpreted as a pixel with attributes such as position, color, normal and texture.

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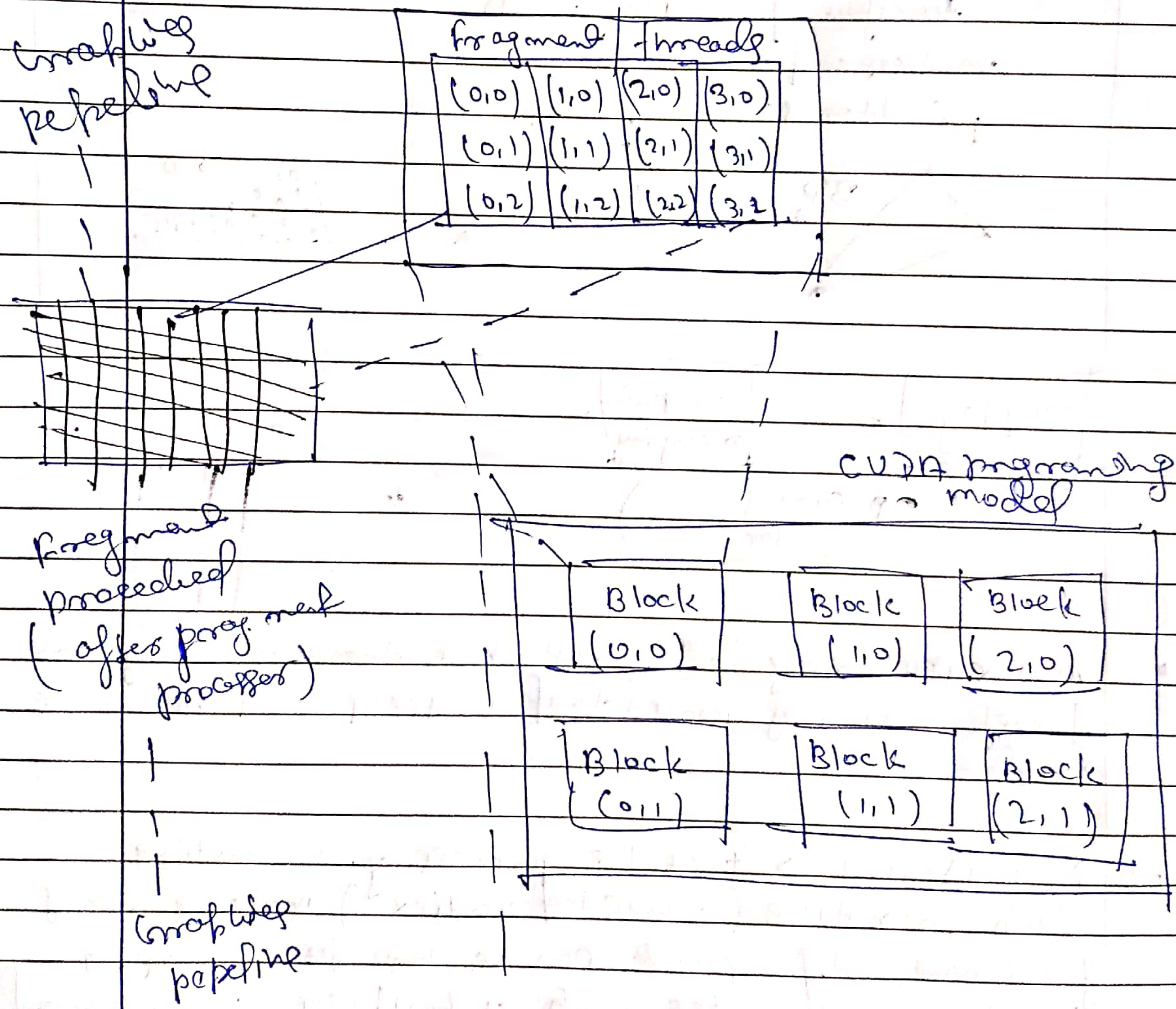
after rasterization:-

- output merging:- this process is concerned with the combining of the ~~fragmen~~ fragments of all primitives in 3D space into 2D color pixel for displaying on screen.



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using CUDA, programmer are allowed to avoid graphics related code. futher, threads within a block are them able to access shared memory as each block is executed on one of serveral multiprocessors of GPU.

The diagram here shows how the CUDA programming model is connected with the graphics pipeline and its relating with the threads.

End